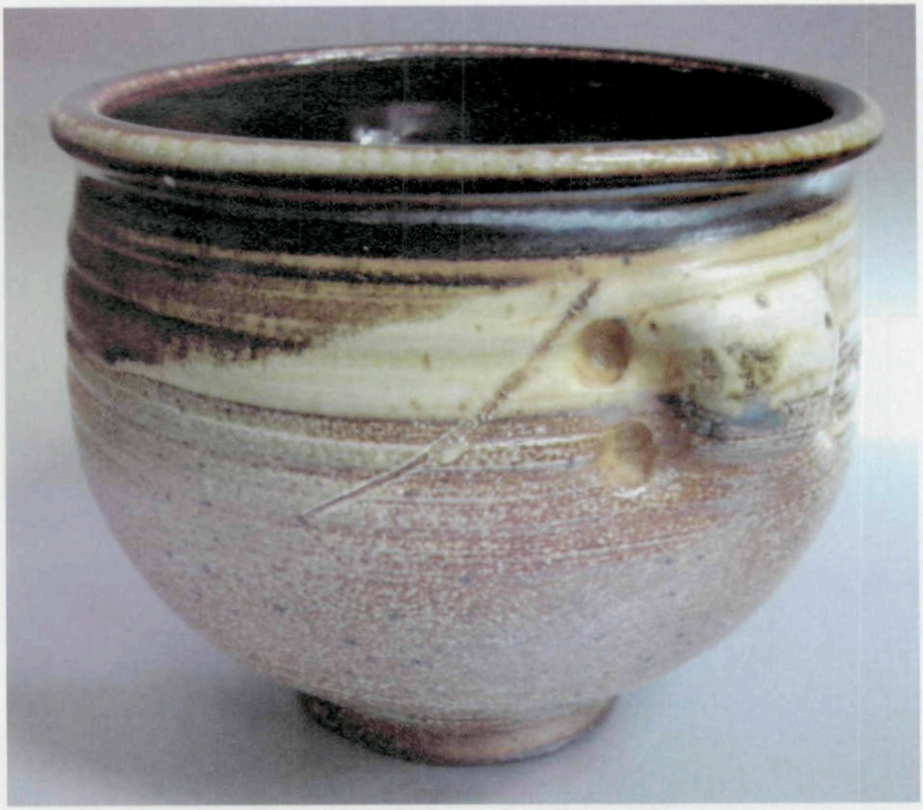
Stoneware Clay Body Formulas

Part 1: The Basics



Understanding how all of the different components of a stoneware clay body work together can help potters develop the best formula for their intended application.

by Jeff Zamek

Stoneware clay is a widely used generic term for clay bodies fired between cone 6 (c/6, 2232°F) and cone 9 (c/9, 2300°F) that create a dense, hard, vitreous, functional piece of pottery or sculpture.* Stoneware clay body formulas can contain just a few raw materials or an amalgam of several different clays, feldspar, flint, talc and grog.

One method of understanding clay body formulas is to think of the total mixture as having three basic parts: *clays*, *fluxes* and *fillers*. Each component helps determine the body's forming characteristics, drying and firing shrinkage, surface texture, fired absorption, glaze interface and fired clay color. Within each part, many different materials can be used to fulfill the requirements. For example, if the stoneware clay body requires flux, many types of feldspars could fill that part of the formula. However, the potter must decide which of the available feldspars will be appropriate for the clay body. The best clay body formulas will have the appropriate raw materials in the correct ratios. Understanding how all of the different components of a stoneware clay body work together can help potters develop the best formula for their intended application.

Clays

Clays are grouped depending on their refractory qualities, particle size, oxide composition, loss on ignition, shrinkage rates, absorption rates and other defining characteristics. The basic clays found in stoneware clay body formulas are high-temperature refractory clays, such as stoneware clays, fire clays, ball clays, kaolins and bentonites. Within each major group are subgroups that further define a particular clay characteristic, such as plastic kaolin (e.g., Grolleg clay) and non-plastic kaolin (e.g., English china clay), and numerous brand names. Each group of clays provides specific attributes to the total clay body formula, including green strength, fired strength, fired color, shrinkage, plasticity, deflocculating potential (zeta potential), texture, forming ability, and reduced warping during drying and firing.

Above: A stoneware pot. Photo courtesy of Jeff Zamek.

*The temperature references to cones are based on large Orton pyrometric cones heated at 108°F per hour.

Although low-temperature clays can be used in stoneware bodies, they are typically limited to below 10% of the overall formula and are primarily used to add color or other attributes. For example, Redart, a low-temperature, high-iron-content clay, is sometimes used in small quantities in stoneware bodies as it contributes a red/brown fired color and additional particle size variation to the total clay body formula.

When certain clays are not available, a substitute can usually be selected from the same group or subgroup. Choosing a clay within the same group helps to ensure that most of the body characteristics will remain consistent. This general rule of substitution works to a greater degree in clay bodies used on the potter's wheel and in hand building forming operations. For example, in throwing bodies, Thomas ball clay can be substituted for Taylor ball clay or Zamek ball clay, all of which are mined by Old Hickory Clay Co. Other factors such as plasticity, green strength, particle size distribution and metallic oxide content should also be considered to fine-tune the formula or obtain the closest possible match when a substitution is needed. Substitutions are more difficult in slip casting clay bodies, where organic content, particle size distribution and other individual characteristics can affect the clay's casting qualities.

Fluxes

Fluxes help lower the melting point of heat-resistant clays and fillers and increase the glass formation in a clay body. A primary goal of a flux is to cause the clay body to melt in a predetermined maturing range. In functional pottery, the maturing range occurs when absorption, shrinkage and fired color are compatible with the glaze, producing a dense, vitreous, non-absorbent clay body.

Every temperature range has an appropriate choice of compatible flux materials. Using the wrong flux or an incorrect amount can have disastrous consequences. For example, a low-melting flux used in a high-temperature clay body can cause over-vitrification, while an over-fluxed clay body can bloat, slump, shrink excessively and fuse to the kiln shelves. Knowing the characteristics of various fluxes can help potters choose groups that work well in their particular stoneware temperature range.

When increasing the flux component of a clay body formula, potters should always form test pieces and place them in a regular production kiln on top of an old kiln shelf. Some potters use small test kilns for this purpose; however, small kilns have faster firing and cooling cycles and less thermal mass compared to the larger production kilns, and can therefore produce different results.

In the c/6 to c/9 stoneware range, feldspars are the best choice of flux. When used alone, feldspars melt at c/6 and are semi-opaque glasses by c/9. The three basic groups of feldspars used in ceramics are soda, potash and lithium. Soda feldspars melt at approximately 100°F lower temperatures than potash feldspars. Lithium feldspars are the most refractory of the group and can produce semi-opaque matte glazes at stoneware temperatures. Within the three groups, many individual feldspars can be chosen for a clay body formula.

A beneficial quality of feldspars in stoneware clay body formulas is their ability to enter into a melt slowly over a wide temperature range. Most successful functional stoneware bodies have a maturing range within two to three pyrometric cones, where they will be dense and vitreous without being over- or under-fired at either end. Talc is sometimes used as a flux in stoneware clay bodies, but it can have erratic fast melting characteristics if it comprises more than 10% of the overall formula.

Fillers

Fillers reduce clay body shrinkage and warping in the drying and firing stages. Flint, pyrophyllite, silica sand, sawdust, mullite, calcined kaolin, kyanite, calcined alumina and grogs of various sizes are the most widely used fillers in stoneware clay body formulas.

While flint can also be considered a glass former, it needs very high temperatures (3200°F) to melt by itself. Only when flint is combined with a flux is its melting temperature decreased. Flint acts as a filler by reducing dry shrinkage and warping in the clay body.

If the amount of filler is too high, the clay body's plastic qualities will be decreased. Clay bodies designed for slab forming and tile making, in which minimal warping and low shrinkage are paramount, usually contain more filler or non-plastic material than throwing bodies.

Other Factors to Consider

Knowing the function of the different materials within a clay body is only half the challenge of developing the right formula. Factors such as the forming method, firing temperature, kiln atmosphere, fired color, intended function of the finished object, and raw material availability and cost also affect the selection of specific raw materials.

Forming Method

Stoneware clay body formulas can be formed on a potter's wheel, constructed from slabs, slip cast, RAM pressed, dry pressed, jiggered or extruded, and each forming method requires a specific combination of raw materials. For example, clay bodies used on a potter's wheel require higher percentages of plastic ball clays compared to dry pressed clay bodies, where the extreme hydraulic pressure of the press forms the object. Slip casting clay bodies will require a deflocculating component—such as sodium silicate, sodium carbonate, Darvan #7 or Darvan #811—to repel the clay platelets and create a clay body that can be easily poured into a mold.

Firing Temperature

It is highly unlikely that a stoneware clay body will perform exactly the same over the entire c/6 to c/9 temperature range. More often, the body will exhibit increased shrinkage and decreased absorption as the temperature increases and as greater verification occurs in the clay body. For this reason, the body should be designed for the specific temperature at which it will be fired by choosing the appropriate fluxes and fillers. While some stoneware clay bodies can be fired anywhere from c/6 to c/9, glaze fit is often compromised due to the different coefficient of expansion rates at either end of the temperature range.

Kiln Atmosphere

A stoneware clay body can be formulated for oxidation, neutral or reduction kiln atmospheres, and each atmosphere can influence the fired color, density, glaze interaction and surface quality of the clay. Neutral kiln atmospheres possess an equal ratio of air to fuel. Oxidation atmospheres contain a higher ratio of oxygen to fuel, causing a cleaner ignition to the fuel and a flat, non-variegated, uniform surface texture and color in the fired clay body. Reduction atmospheres feature a higher fuel-to-air ratio, which causes carbon monoxide to pull oxygen from the oxides contained in clays and glazes. Metallic oxides such as iron and manganese fired in reduction kiln atmospheres tend to flux the clay or glaze to a greater degree than in oxidation atmospheres. Potters who fire their ware in a reduction atmosphere must take great care when using clays with a high organic content. If the organic material is not removed during the first part of the bisque firing, it can result in bloating or black coring in subsequent glaze firings. Carbon can also be introduced if a reduction kiln is fired improperly.

A stoneware vase. Photo courtesy of Jeff Zamek.

Fired Color

Each type of clay possesses varying amounts of iron, manganese or other metallic oxides that contribute to the body color of the fired clay. For example, some fire clays will fire to a light cream color, while other fire clays will fire to dark brown, depending on their metallic oxide content. Generally, high-iron-content clays produce darker fired colors, while clays with a low metallic oxide content, such as kaolins, will contribute to a white or light fired clay body color. White clay bodies can be developed into yellow, blue, green or other colors by adding body stains or metallic coloring oxides.

It is important to note that glazes will look different depending on the underlying clay body color. For example, copper red glazes will have a greater vibrancy when placed on white clay bodies than on darker clay bodies.

Function

The function that the finished clay body will perform is an important consideration in raw material selection. For example, clays for sculpture will be used in large-scale and/or thick cross sections, and should exhibit low shrinkage and warping. Sculpture formulas can contain non-plastic materials, such as molochite, grog, mullite, silica sand, pyrophyllite, kyanite, wollastonite, nylon fibers and fiberglass fibers, as well as coarse-particle, low-shrinkage clays such as fire clays. Clay bodies that will be used for products subjected to freeze/thaw conditions must allow for expansion and contraction and are typically formulated from stoneware, ball clays and fire clays as well as flint, feldspar and grog. In functional pottery, the unglazed clay body must hold water and be non-absorbent. The glaze functions as an aesthetic element contributing color or surface texture, in addition to providing a smooth surface for easy cleaning of the ware; however, it cannot prevent moisture from penetrating the clay body.

Raw Material Availability

The availability and price of raw materials is also a factor in the development of a clay body formula. Just because a certain type of feldspar or clay was available several years ago doesn't necessarily mean it can still be obtained, or that it can be obtained at an affordable price. The industrial market dictates the supply and cost of any given clay body material, so potters should be prepared to make changes.

For commercial ceramic supply companies that mix clay, the shipping cost of the clay can be a major factor in competing in the market. Some materials that are readily available on the East Coast might not be available on the West Coast, since the shipping cost can equal or surpass the actual price of the material.

The Perfect Body

A "perfect clay body" is a subjective term, but the chances of reaching such an ideal goal increase when the appropriate ratio of clay, flux and fillers is used. When designing a clay body formula, potters should understand the role that the different materials play, and remember to take into account factors such as the forming method, firing temperature, kiln atmosphere, fired color, intended function of the finished object, and availability and cost of the raw materials. These basic principles are the foundation for success.

Editor's note: Future articles in this three-part series will examine a specific stoneware body formula and discuss plasticity. Look for Part 2 in the fall edition of *Pottery Production Practices* (published in October).

About the Author

Jeff Zamek received bachelor's and master's of fine arts degrees in ceramics from Alfred University, College of Ceramics, Alfred, N.Y. He taught ceramics at Simon's Rock College in Great Barrington, Mass., and Keane College in Elizabeth, N.J. In 1980 he started his own ceramics consulting firm and has contributed articles to *Ceramics Monthly, Pottery Making Illustrated, Clay Times, Studio Potter* and *Craft Horizons*, in addition to *Pottery Production Practices*. His books, *What Every Potter Should Know* ($31.45) and *Safety in the Ceramics Studio* ($25.45) are available from Jeff Zamek/Ceramics Consulting Services, 6 Glendale Woods Dr., Southampton, MA 01073. These books can also be ordered online at www.ceramicindustry.com, through *Ceramic Industry*'s online bookstore.